ZOOLOGIA 35: e23133
ISSN 1984-4689 (online)
zoologia.pensoft.net

RESEARCH ARTICLE

Assessing the population density of the spotted paca, *Cuniculus paca*, (Rodentia: Cuniculidae) on an Atlantic Forest island, southeastern Brazil

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http://zoobank.org/E92572BC-C948-44A8-B384-6773FB58CA7A

ABSTRACT. The spotted paca, *Cuniculus paca* (Linnaeus, 1766), is a Neotropical, opportunistic, frugivorous caviomorph rodent, that inhabits primarily broadleaf forests. We aimed to provide the first estimates of density of *C. paca* for the Ilha Grande, an island located in the Atlantic Rain Forest biome of Brazil. Density and population size were estimated using the total number of individuals observed along each trail through the program DISTANCE 7. Our estimates of density and population size reinforces the importance of the Ilha Grande as an important reservoir of the species. Therefore, the results presented herein can be a starting point to support future action plans for the species, making predictions regarding the ecosystem and management and conservation of the spotted paca. Furthermore, the results can be used as a surrogate for other regions in which the species occurs.

KEY WORDS. Abundance, Distance sampling, Ilha Grande State Park, Line-transect.

INTRODUCTION

Estimates of density and population size are fundamental to any conservation effort of endangered species. These estimates allow to evaluate a great range of impacts such as loss of habitat, identifying priority areas for conservation, evaluating the viability of isolated populations, determine the species conservation status, and has utility in several ecological studies in addition to serving as an important tool for decision makers (e.g., Jathanna et al. 2003, Tomas et al. 2004, Cardillo et al. 2006, Cunha and Loyola 2011, Buckland et al. 2016). However, such information is rare for most taxa, including endangered species, especially in the Neotropics (Cardillo et al. 2006, Cunha and Loyola 2011).

The spotted paca, *Cuniculus paca* (Linnaeus, 1766), is a Neotropical, opportunistic, frugivorous caviomorph rodent, that inhabits primarily broadleaf forests (Collett 1981, Pérez 1992, Aquino et al. 2009, Goulart et al. 2009). The species presents nocturnal habits, being able to eventually present crepuscular and dawn activity (Gómez et al. 2005, Michalski and Norris 2011). The spotted paca is listed as Least Concern both in the global and Brazilian red lists in view of its wide distribution, presumed large population, occurrence in a number of protected areas (Ministério do Meio Ambiente 2014, Emmons 2016). However, local extinctions have occurred in the southeast of its range due to habitat fragmentation and poaching (Emmons 2016). Despite its conservation status, the spotted paca is of conservation and management interest throughout their geographic range, because it is a popular game species for people, an important prey of large carnivores, and an important seed disperser (Dubost and Henry 2006, Aquino et al. 2009, Foster et al. 2010). Currently, estimates of density and abundance of the spotted paca are limited to few studies that used the most frequently methods employed, such as sightings; indirect records, and camera traps (e.g. Collett 1981, Beck-King et al. 1999, Asprilla-Perea and Lopez-Perea 2011, Santos-Moreno and Perez-Irineo 2013). Spotted pacas may be locally abundant but estimated population parameters can be laborious and results are likely to be unsatisfying (Beck-King et al. 1999). Few studies employed nocturnal surveys (e.g., Glanz 1990, Malcolm 1990, Beck-King et al. 1999, Oversluijs-Vásquez 2003, Aquino et al. 2009), and a great part of knowledge about the species natural history comes from studies that focus on the species as a feline prey.

In this context, we aimed to provide the first estimates of density of *C. paca* for the Ilha Grande, an island located in the Atlantic Rain Forest biome of Brazil. We also discuss the importance of performing nocturnal samplings for estimating density of species such as *C. paca*.

MATERIAL AND METHODS

Our study was carried out in Ilha Grande State Park (PEIG), an island (Ilha Grande) located in the Southwestern coast of Rio de Janeiro State, Brazil (Fig. 1). PEIG is the second largest insular strictly protected park in Brazil managed by Brazilian authorities and covers some 120 km², over half (62%) of the 193 km² area of Ilha Grande. The climate is tropical, hot and humid, without a dry season. Ilha Grande is the top of a submerged mountain and has two dominant types of topography, mountain and coastal plain. Mountain peaks occur in the center of the island. Almost half of the area (47%) is covered by dense, relatively pristine Atlantic rainforest. Secondary forest, in an advanced successional stage, is the second major habitat type (43%). The remaining areas comprise rocky outcrops with herbaceous vegetation (7%), salt marsh, mangroves and beaches (2%), and 1% human settlement (Alho et al. 2002). Although the area occupied by human settlement is small, it is concentrated around the northern coastline of Ilha Grande Bay and in settlements such as Abraão village.

During the period between December 2003 and May 2005, 128 transects were performed, totaling 401.3 km walked in 382 hours of effort. The transects were surveyed in five existing dirt trails in Ilha Grande to minimize the impact of opening new trails (Fig. 1, Table 1). These five trails covered all vegetation types found in the Ilha Grande and crossed several streams. Two of those trails are located in the northern part, connecting the largest settlement on the island, the Abraão Village, the beaches of Palmas and Feiticeira (respectively T01 and T02). The other three trails are on the south side, connecting the Dois Rios Village to Caxadaço and Parnaióca beaches, and the place known as Jararaca (respectively T03, T04 and T05). Transects ranged in length from 2.1 to 6.7 km. Transects were walked at times when the species are at increased activity: at dawn and twilight/night following sunrise and sunset hours along the year (Gómez et al. 2005, Michalski and Norris 2011). Thus, they were divided into two categories: dawn and twilight/nocturnal transects. Transects were walked at an average speed of 1.1 km/h (± 0.5).

For each sighting, we recorded the perpendicular distance of the animal from transect (measured using measuring tape),

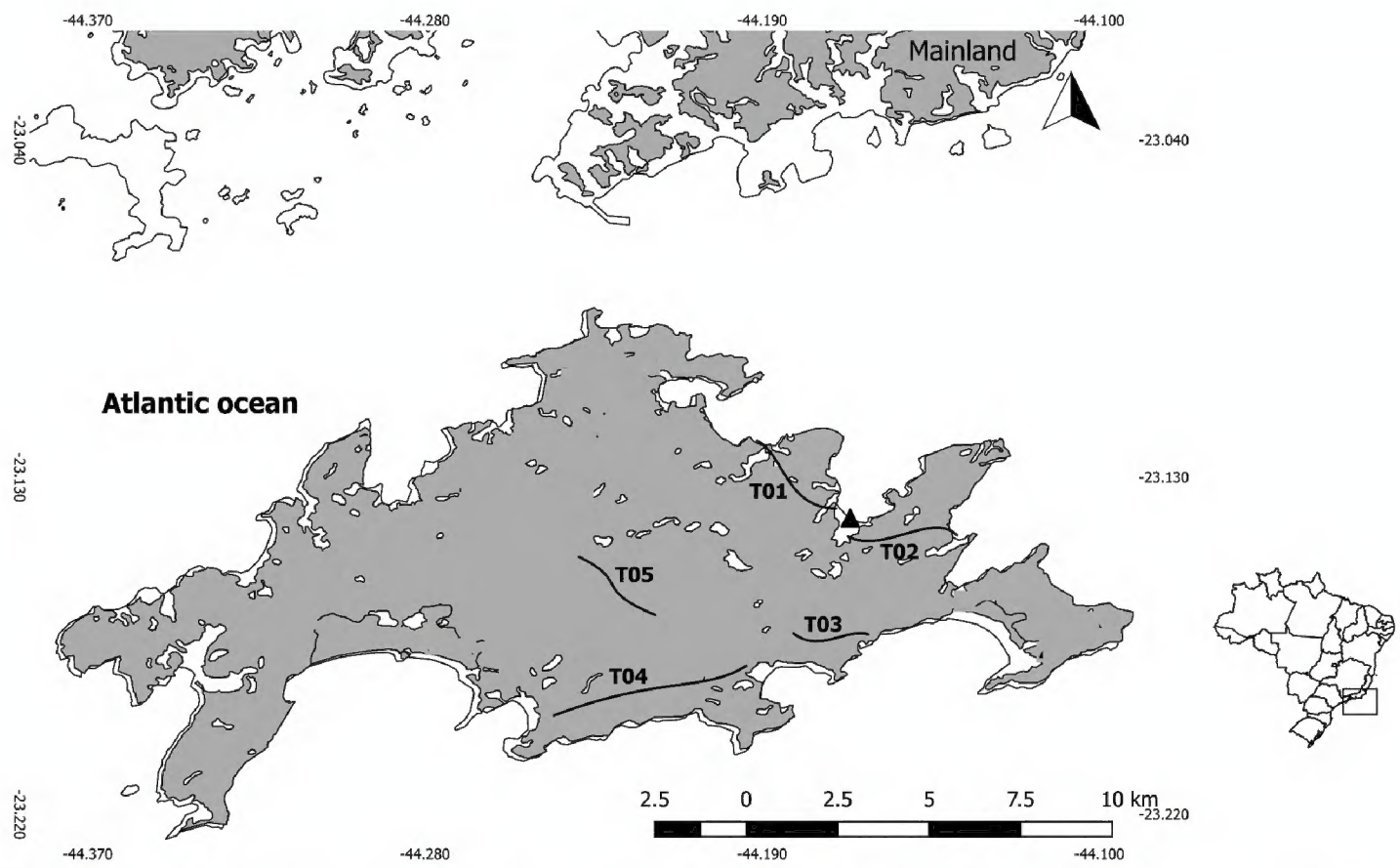

Figure 1. Ilha Grande in the state of Rio de Janeiro, Brazil and location of the transects. Black triangle representing the Abraão village.

Table 1. Characteristics of transects (length, altitude and region), number of times each transect was walked (N samples), total kilometers walked, and the encounter rates of *Cuniculus paca* per transect.

Transect	T01	T02	T03	T04	T05	Total
Coordinates	23°07'37.4"S 44°10'47.3"W	23°08'43.3"S 44°08'53.5"W	23°10'07.9"S 44°10'24.9"W	23°11'26.2"S 44°13'43.5"W	23°09'25.4"S 44°14'19.6"W	
Extension (km)	2.1	2.3	2.7	6.7	2.1	15.9
N samples	27	23	27	24	27	128
Total Km walked	56.7	52.9	72.9	160.8	56.7	401.3
Cuniculus paca	0	2.26	0.41	0.18	0.18	0.62

the length of transect walked to that point, date, and timing of the record. Individuals of spotted paca were detected using a head-flashlight. Density and population size were estimated using the total number of individuals observed along each trail through the program DISTANCE 7 (Buckland et al. 2001). DISTANCE uses the perpendicular distances to the observed animals to estimate effective strip width (ESW) in the study area and model the detection function that best suits the probability of detection of an animal at a given distance (Buckland et al. 2001, Thomas et al. 2010). The best detection model is selected by the Akaike Information Criterion (AIC; Akaike 1973).

RESULTS

Throughout the surveys, *C. paca* was only recorded at night and we obtained 42 observations. Estimated density for *C. paca* was 35 ± 3.2 individuals/km² and estimated population size for the entire Ilha Grande was 6755 ± 617 individuals. The effective strip width (ESW) was 3.40 ± 0.58 m with records obtained from 0 to 9 m from the line of the transect (Fig. 2). The model which best fitted our data was a Hazard rate with cosine adjustment. The coefficient of variation for both density and population size was 18.22%.

DISCUSSION

Spotted paca density, estimated in the Ilha Grande through transects, is the first estimate for the area and showed a coefficient of variation below 20%, which is the maximum value recommended to obtain reliable estimates (Buckland et al. 2001). This indicate precision in the estimates and can assist in the species' conservation as starting point for monitoring the species in the Ilha Grande. Density estimated for the species in the Ilha Grande is within the range observed in Neotropics forests, with a population density range of 25-70 adults per square km depending on the habitat (Patton 2015). In fact, estimated densities range from 3.5 individuals/km² in Peru (Emmons 1987) to 93 ind/km² in Puente Gloria, Colombia (Collett 1981). This intermediary density can be explained by the absence of larger predators such as *Panthera onca* (Linnaeus, 1758) and *Puma concolor* (Linnaeus, 1771) in Ilha Grande (Lessa et al. 2017) which allows to increase the spotted paca density in the island. In fact, prey species such as spotted pacas are thought to have lower densities in areas in which top predators are present (Terborgh and Winter 1980, Wright et al. 1994). However, despite the absence of large predators, the region is impacted by both poaching and invasive species such as *Canis lupus familiaris* Linnaeus, 1758 (Lessa et al. 2017), which could be reducing species density. Thus, highlighting the importance to monitor the population of the species in the long term that despite being listed as Least Concern by the global and Brazilian red lists have become locally extinct in some locations due to poaching (Emmons 2016).

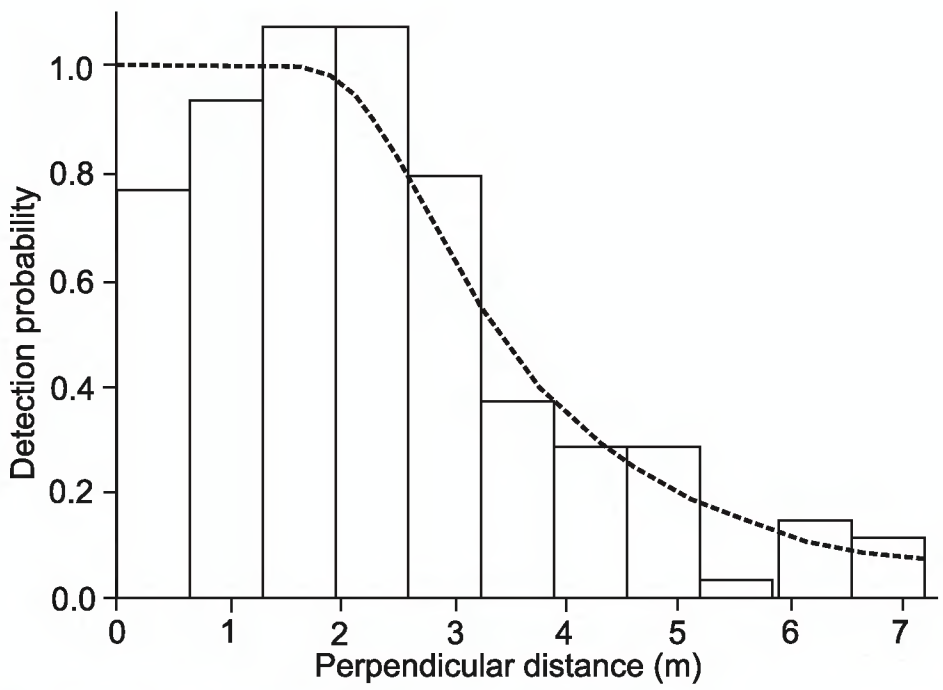

Figure 2. Plot of the detection function for spotted pacas based on the AIC selected Conventional Distance Sampling (CDS) model. Histogram represents the probability of detection for each distance interval. The curved line is the detection function, showing the probability that a spotted paca is observed as a function of distance from the transect line.

Although some authors avoid collecting data in nocturnal transects (Duckworth 1998), this study has shown that they provide a good amount of data for the spotted paca that is lacking density estimations in the Atlantic Forest. Since most of the Neotropical mammals have predominantly nocturnal habits (Eisenberg and Redford 1999, Paglia et al. 2012), a higher sampling effort in this time range is required to obtain sufficient data to estimate the density of these species. It is worth mentioning that in the zero-distance perpendicular to the transect, the probability of detection is lower than in the first meter as showed in Fig. 2. This is due to the fact that for nocturnal animals, eye brightness is the most important detection method (Pereira et al. 2017). Therefore, if the animal is too close, the angle may not allow you to have the vision of the eye glow. This must be taken into account when performing the analysis to avoid bias in the density estimation as suggested by Buckland et al. (2016).

The estimate presented here is the first for the Atlantic Forest using distance sampling. Our estimates of density and population size reinforces the importance of the Ilha Grande as an important reservoir of the species. Therefore, the results presented herein can be a starting point to support future action plans for the species, making predictions regarding the ecosystem and management and conservation of the spotted paca. Furthermore, the results can be used as a surrogate for other regions in which the species occurs.

ACKNOWLEDGEMENTS

We thank the Centro de Estudo Ambientais e Desenvolvimento Sustentável (CEADS) and the Universidade do Estado

do Rio de Janeiro (UERJ) for the logistical support during the execution of this research. We also thank the Instituto Biomas for financial support. BCP is also grateful to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) for a graduate scholarship. HGB thanks grants from FAPERJ (E26/201.267/2014), CNPq (307781/2014-3) and Prociência/UERJ.

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Submitted: December 19, 2017
Accepted: February 15, 2018
Available online: November 22, 2018
Editorial responsibility: Diego Astúa de Moraes

Author Contributions: ACF, BCP and HGB contributed equally to this article.
Competing Interests: The authors have declared that no competing interests exist.
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